Vegetation Resources Inventory

Within-Polygon Variation Sampling Procedures

Prepared by
Ministry of Sustainable Resource Management
Terrestrial Information Branch
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For further information about the Resources Information Standards Committee, please access the RISC website at: http://srmwww.gov.bc.ca/risc/.

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For questions concerning the content of this publication please contact the:

Vegetation Resources Inventory Coordinator
c/o Ministry of Sustainable Resource Management
Terrestrial Information Branch
PO Box 9993, 722 Johnson Street
Victoria, BC V8W 9R7

Phone: (250) 387-1314
Fax: (250) 387-5999

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Introduction

Background

One of the typical questions which is asked of any inventory is "How accurate is a *specific* polygon after adjustments are made and a final inventory database is available?" This is an important question for harvest planning and for timing silvicultural treatments where a specific polygon is grown, treated and harvested. It is therefore desirable to provide users with some indication of the accuracy of these individual polygons. That is, the inventory process needs to answer this question:

> *If I check the volume of an individual polygon in this inventory, what difference should I expect to find?*

There are some indirect ways to try to compute this value, but they depend on assumptions that are not always reasonable, and on complex statistical arguments. A direct check on the polygon accuracy is easier to understand and interpret. The process of carrying out this direct check is called Within-Polygon Variation (WPV) sampling and is the subject matter of this document. This document is based on the report, *Establishing Polygon Accuracy by Sampling for "Within-Polygon Variability (WPV) in the Vegetation Inventory of British Columbia, 1998*, prepared for the Ministry of Forests (MoF) by Kim Iles of Kim Iles and Associates. This report is available from the Ministry of Sustainable Resource Management (MSRM), Terrestrial Information Branch in Victoria.

Objective

The objective of WPV field sampling is to give users a reasonable expectation of the difference they should expect to find when they "check the timber inventory" in the field, as well as an estimate of the actual error of the adjusted polygon database. In addition, it establishes a sampling protocol for measuring polygon error rates for other resource values. Polygon error will be expressed as a percentage difference in the polygon values, except in cases of stands of small average diameter trees where actual (absolute) units may be used. A detailed discussion of the interpretation and uses of WPV data is given in Appendix A.

The WPV is an important supporting activity for the Vegetation Resources Inventory (VRI) process. Checking the inventory using WPV provides credibility to the inventory results obtained from the VRI process.

Variables to Measure

The field work will aim at describing only a few main timber parameters, including:

- gross volume,
- site index,
- basal area, and
- species percentages.

Basal area and species percent are of particular interest as well as being very easy and quick for users to check in the field. In addition, these measurements are well correlated to volume and value. The errors in volume and value for most forest sampling in B.C. are dominated by

the error for these two parameters. Therefore, the analysis should concentrate on basal area and species percent as the standard error rate comparisons.

Percentage errors based on basal area will be a valid guide to errors in other estimated parameters. If the inventory is readjusted in the future (without direct reference to these measurements) then the revised inventory can be evaluated with this same data - there is no need to resample.

The stated answer for the polygon, or any corrected value for the polygon, is for the average over the entire polygon, not some "typical" portion. Therefore, WPV sampling will cover the entire polygon, with appropriate edge effect measures taken near the polygon boundary.

2. Office Procedures

2.1 Preparing a Sampling Plan

This section outlines the steps for preparing a sampling plan for WPV sampling. The sampling plan should be approved before the field work begins. The approval process should be done quickly and efficiently to avoid confounding field measurements with sample selection problems. Sample planning steps typically include:

- A description of the set of polygons to be checked (population);
- Stratification and weighting criteria;
- Procedures for selecting sample polygons, and sampling locations within those polygons;
- Setting the sample size (number of sample polygons and the number of plots per polygon).

Each of these steps is described below.

2.2 Population

Identify the inventory unit of interest, which could be a TSA, TFL, Forest District, IFPA, or some other subset of polygons.

2.3 Stratification

Stratification is the process of dividing the inventory unit into subpopulations called strata. Stratification does not need to be used unless the project manager has reason to believe that there are sets of polygons which have a markedly different actual accuracy. In this case, that type of polygon could be a different stratum. The only standard stratification would be for areas with trees large enough to sample versus areas with trees which are too small. This stratification must be checked in the field, not based on the database values.

2.3.1 Sampling Unit

A population is normally divided into non-overlapping parts called sampling units before the sample is selected. In WPV, a sampling unit is defined as a polygon. The individual polygons in the inventory unit are the potential locations for taking observations.

Observations (samples) are made inside each polygon. They are taken from a cluster of well-distributed plots inside the polygon. The plots may be fixed-area plots or prism plots.

2.3.2 Weighting Observations

In the statistical estimation or correction, data must be weighted appropriately to account for the sample selection probabilities.

The weighting in this instance should be approximately the same for each plot inside a polygon. It might be affected by the strata size if there is more than one stratum. Since the polygons are already chosen proportional to area, the proper statistical weight (w_i) for one plot is calculated as:

$$w_i = A/n$$

where A is the area of the stratum interest, and n is the number of plots in the stratum.

For example, if the area (A) of a stratum is 451,358 ha, and there are n = 200 plots in the stratum, then:

$$w_i = 451{,}358 / 200 = 2256.79 \text{ ha.}$$

2.3.3 Recording Weighting

Details of the placement and weighting of the polygons should be recorded in the database, and the records checked for correctness. This means that there should be a "Comments" section in the database for each polygon, and the comments should be easily retrievable by users, planners, and reviewers.

2.4 Sample Selection Procedures

Polygons should be selected with a probability proportional to their area. The samples should be selected by the standard VRI sample selection procedure, which is sampling with Probability Proportional to Size With Replacement (PPSWR). The selection should be from the entire inventory area. In some cases it will be from one particular stratum within the entire area.

The selection process, which is similar to that described for VRI ground sampling, involves two steps:

2.4.1 Select a Polygon

Use existing polygon borders and areas for the entire inventory unit.

1. Compile a list of all the polygons and their areas.
2. Use the current PPSWR sample selection procedures as described in Appendix C to select the sample polygon.

2.4.2 Determine the Plot Locations Inside a Polygon

A grid pattern should be used for the installation of plots inside a polygon. The starting point for the grid should be randomly chosen in a rectangle which surrounds the entire polygon. An initial point should be chosen inside the rectangle, and if it is within the polygon it will be the starting point for the grid—otherwise, random numbers should be chosen until one falls within the polygon and will serve as the starting point. A grid that will approximate the desired sample size should then be applied, and when this results in slightly more or fewer plots then that is acceptable, providing that the sample can still be done in whole-day increments. If too many locations are chosen by the approximate grid, eliminate the extra ones randomly and document the process.

The distance D between grid points can be determined using the equation:

$$D = \sqrt{\frac{10000 * A}{n}} = \sqrt{\frac{10000 m^2 * 9.1 ha}{10}} = 95 \text{ metres}$$

where: D = interval between grid points in meters;
A = area of polygon in hectares (e.g. 9.1 ha); and
n = number of plots (e.g. 10 plots) to be established within a polygon.

Once the distance between the grid points has been established, a random point should be selected within the polygon (Point #7, Figure 2.1) From this point, the other points should be established within the polygon at an equal distance (D) in cardinal North:South, East:West directions. The project manager has the option of orienting the grid in a direction other than the cardinal directions. For field crew convenience the grid point spacing can be adjusted slightly to some even value such as the nearest 5 metre or 10 metre distance.

In Figure 2.1, for instance, full measure plots could be installed at locations #4, and #8, and count plots in the remaining locations.

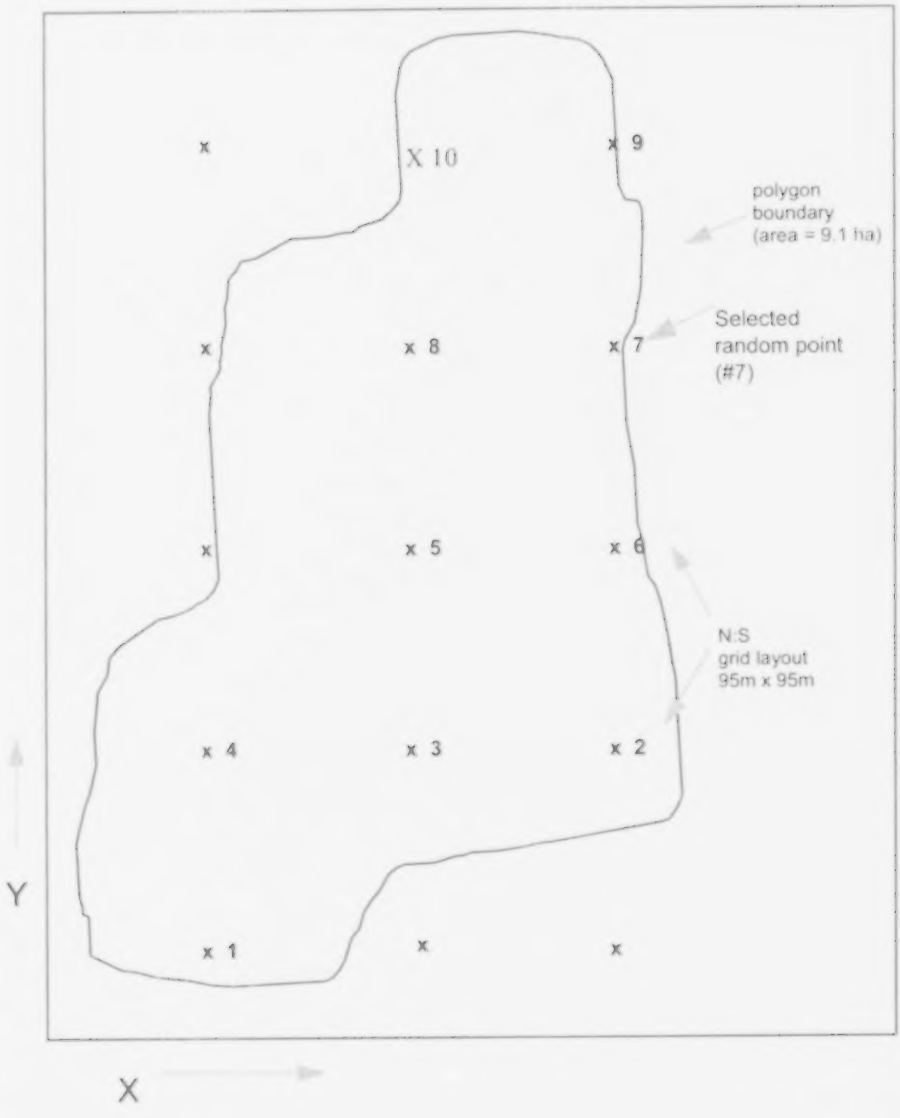

Figure 2.1: Selecting sample locations within a sample polygon.

2.5 Setting the Sample Size

2.5.1 Number of Sample Polygons

From the theory of sampling for percentages, typically the number of samples needed to estimate the percentage of acceptable polygons in the population of interest with good precision is large (> 100). This would make WPV sampling overly expensive. Initially, the sample size will be kept small until we gain experience with WPV sampling. Therefore, an arbitrary sample size of 10-30 polygons is suggested for each inventory unit. This suggested sample size should be treated as a general guideline, not an exact requirement. The sample size used in practice is usually a trade-off between the suggested sample size and the expected cost and timing of the sampling. The suggested sample size range may be increased arbitrarily to allow for post-stratification, and more flexibility in use of the WPV data.

2.5.2 Number of Plots per Polygon

Sample size for a polygon is selected to represent two or more days of work. This will vary with access to the area. The goal should be to have approximately 20-50 plots in the polygon. MSRM recommends installing 30 to 32 plots within each polygon, but the number could vary from project to project depending on crew workload, polygon variability and end product needs. Once determined, a fixed number should be used for an entire project. For instance, if a project manager chooses to install 24 plots, all WPV polygons should have approximately 24 plots.

Counted Trees vs. Measured Trees

All trees in all the plots will be counted and only a portion will be measured. There are two methods of selecting which trees to be measured. One is traditional and simpler. The second is more efficient and flexible, but newer. The project manager must decide which process to use, but if the newer method can be made effective and routine then there are certainly advantages. The results can be freely mixed from each of these methods. There is no problem combining the final values for different polygons. The difference is strictly in processing the data.

Method 1: All trees in a plot are measured. Measure all of the trees on every 3rd, or 4th plot, depending on selected number of plots to be established in sample polygons. That is, every 3rd or 4th plot is a *full measure plot* and the remainder are *count plots*.

The plots to measure can be determined ahead of time in 4 patterns (Appendix B), and one of the patterns is randomly chosen by the project manager. The full measure plots may also be established using a systematic grid.

Method 2: The "distributed measure-tree method". The trees to measure are chosen with a large angle gauge. If a 9 BAF prism was used to count trees, then a BAF of "X" times larger is used to choose approximately 1/X of the trees during the cruise. If roughly every 4th tree is desired, then a 36 BAF gauge would be used. This is most easily done with a Relascope. The exact relationship of one BAF to the other is not important, only a roughly appropriate multiple is needed.

This process distributes the measured trees throughout the stand, and gives increased accuracy to the cruise. A ratio of 1:4 is recommended initially. For example, for 40 plots, with an average count of 6 trees /plot, this would be

roughly 240/4 = 60 trees. The exact number of trees will be variable, just as it is with the usual method of variable plot sampling.

With both of these methods, the process of insuring that at least one tree of each species is measured should be followed, just as in the Vegetation Resources Inventory and in standard cruising practice. It is suggested that the first tree of any species is measured, and if another one is selected during the cruise then that "insurance tree" would be dropped from the computation.

Method 1 – the use of a mixture of count plots and full measure plots – is recommended initially. The newer, more efficient method may be introduced as more experience is gained with it.

2.5.3 Establishing the Sampling Method

Selecting the Sampling Method

The sampling design accommodates the use of either variable-radius plots or fixed-radius plots for the sample. Once selected, the sampler will maintain the plot type throughout the polygon.

The project manager will select the sampling method to be employed for each polygon prior to the field sampling, using the guidelines below.

- Variable-radius plots would normally be used in most stands in the inventory.
- Fixed-radius plots would normally be used in the following situations:
  - stands expected to have less than 15 m2 of basal area,
  - stands with sapling-sized regeneration,
  - non-treed polygons.

The design specifies a fixed plot size of 5.64 m radius. Using only one plot size eliminates a potential source of bias which could be introduced if crews change the plot sizes in the field to obtain some desired tree count.

3. Field Procedures

3.1 Introduction

This section deals with the identification and collection of detailed tree information from which volume can be calculated and site potential can be determined. Trees may be sampled using variable-radius plots or fixed-radius plots.

3.2 Objectives

- To collect attributes for the calculation of tree and stand volumes, basal area and species distribution.
- To collect site index information.

3.3 General Procedures

Locating the tie point and locating individual count and measure plots is described in this section. Tree measurements are also discussed in this section as they appear on the field cards, but the field crew is free to measure attributes in the most efficient sequence. The steps are discussed in the following order:

1. Select and establish tie points, establish cruise strips and plot establishment
2. Select a suitable basal area factor, and identify trees to measure.
3. Identify and record tree attributes.
4. Establish a fixed-radius plot for site tree measurements.
5. Select and record site tree data.
6. Identify and record trees by species and DBH on count plots, and additional measurements on new species, if required.

3.4 Field Cards for this Section

Polygon Sampling Header Card (PH) (Appendix E)

Polygon ID, project ID, sample plot information, crew, dates, tie point information

Polygon Compass Card (PC) (Appendix E)

Tie point details, field map and notes

Polygon Sampling (PS) (Appendix E)

Tree number, species, status, DBH, remaining bark, lengths

Polygon Site Tree Data (PT) (Appendix E)

Top height and site tree data, GPS data

3.5 Detailed Procedures

3.5.1 Select and Establish Tie Points, Establish Cruise Strips and Plot Establishment

Establishing Tie Points (Field Card PH and PC)

Tie points will be established for all polygon sampling. The tie point should be a feature recognizable on the map, ground and photo. The tie point will be ribboned with two sets of ribbon with the polygon number, crew initials and the bearing and distance to the first plot marked on the ribbon. The colour(s) of ribbon to use should be determined on a project specific basis at the pre-work conference. If desired, a baseline through the polygon can be installed to assist in locating plots. The cruise plot grid or baseline should also be tied to recognizable features at several locations in or adjacent to the polygon to assist in mapping the location of the completed plots.

Establishing Cruise Lines

Cruise lines between plots will be chained. The plot grid layout will be provided to the field crew prior to sampling (see Appendix F for an example of a sample location map). The lines between plots should be ribboned to assist relocation of the plots for the short term audit of the samples. Recording the bearing and distances between plots at each plot centre and at intervals halfway between plots if plot spacing is greater than 50 metres may assist the auditor in relocating the plots. The field crew will record significant timber type breaks, terrain features such as creeks, rock bluffs, others, and man-made features such as roads, fences and other features of interest.

Establishing Plot Centre and Numbering Plots

A wooden stake (cut stake from adjacent saplings or pre-cut wood stake) should be firmly established in the ground at the plot centre. A tree adjacent to the plot centre should be wrapped with a double ribbon with the plot number, date and crew initials on the ribbon. The plots may be numbered on the cruise layout map prior to the field location or numbered as they are completed at the option of the project manager.

Establishing Full Measure and Count Plots

The field crew will be provided with a polygon map indicating the full measure versus count plots. Normally, the ratio of full measure plots to count plots will be in a ratio of 1 full measure to 4 count plots. The full measure to count plot establishment ratio may be altered on a project specific basis by the project manager.

3.5.2Establishing Plot Layout, BAF, and Partial Plots

Selecting the Basal Area Factor (BAF)

The variable plots and 5.64 m fixed-radius plots are used to measure trees.

Objectives

The primary objective is to have an accurate tally of trees at all points. A secondary objective is to have an efficient number of trees for analysis.

Basal Area Factor

The optimum basal area factor (BAF) will result in an average of 6 to 8 **live** trees per plot within the polygon. A sample plot may have fewer than 6 live trees or more than 8, but over the entire cluster an average of 6 to 8 live trees per plot is desirable.

In stands with high numbers of dead trees, the average number of live trees may be considerably less. If the tree count is consistently below or above the desired range of trees, the project manager will need to review the process for deciding BAF.

The sample size should ensure efficient volume and basal area measurements and minimize non-sampling error due to excessive or difficult measurements. In areas with reduced visibility or difficult ground to sample, the BAF size may be increased to reduce the potential for measurement error.

The selected prism size (BAF) should be used throughout the sample cluster. The selection of this BAF must be determined prior to arrival at the initial plot centre. A number of ways to select the appropriate BAF are discussed below.

Procedure

1. As you approach the sampling site within the polygon quickly do tree counts using various prism sizes. A substantial reconnaissance may be required in polygons with high basal area variability.
2. In areas with restricted visibility, choose a BAF that minimizes the potential of missing trees.
3. Each polygon will have an estimated basal area assigned during the photo interpretation phase. The basal area divided by the desired tree count may provide guidance to the approximate prism size to select.

   The approved BAFs are listed in Table 3.1. The approved BAFs are limited to discourage switching prisms to obtain some "desired" tree count by the sampler, as this can create a potential bias. All measurements will be recorded using metric BAF. The smallest prism size is set at a metric 5 BAF to reduce the plot radius to a reasonable distance and avoid missing trees. **Project managers may select a smaller prism size such as a 3 BAF in specific conditions as long as the objectives are maintained.**

Table 3.1: Approved BAFs to be used.

Prism size in m^2/ha	Diopter	Relaskop value in m^2/ha	Diopter
5.00	4.472	5.06	4.500
7.00	5.292	6.25	5.000
9.00	6.000	9.00	6.000
12.00	6.928	12.25	7.000
16.00	8.000	16.00	8.000
20.00	8.944	20.25	9.000
25.00	10.000	25.00	10.000

4. Once you have selected a BAF for the polygon , keep that size throughout the polygon

5. If the BAF selected results in too many tree measurements, which can result in non-sampling errors, split the plots using the procedures discussed below.

Measuring Borderline Trees "In" and "Out"

The objective of the inventory is to correctly determine which trees are within the plot. The procedure will vary by plot type. The centre of a tree at DBH will be used to check the borderline distance.

Fixed-Radius Plots

1. Correct all measurements to horizontal distance.
2. Use the central point of the tree stem at DBH to determine if the tree is "in" or "out" of the sample. This central point is generally equated with the tree pith.

Variable-Radius Plots

Use a prism or relaskop to select trees for measurement only when the tree can be clearly determined to be "in" or "out". If the observed DBH is not obviously in or out, measure the tree for DBH and compare the horizontal distance with its plot radius. If you are not able to clearly decide if a tree is "in" or "out," you must measure it.

Measure the horizontal distance from the plot centre to the centre of the tree at breast height on the side of the tree. Compare the horizontal distance to the calculated plot radius for the tree (DBH * PRF). If the horizontal distance is within the tree plot radius, the tree is "in". If the horizontal distance is greater than the tree plot radius, the tree is "out." If the measured horizontal distance is within 10 cm of the tree plot radius, re-do the horizontal distance by measuring from the plot centre to the face of the tree and add ½ the tree diameter at DBH. If the total horizontal distance is greater than the tree plot radius, the tree is "out."

An additional method of determining if trees are "in" or "out" of the large tree plot is to use the plot radius factor to the tree face [PRF_f]. The plot radius factor to the "tree face" is the plot radius factor to the tree center [PRF c] less 0.005.

Using this method, the horizontal distance from the plot center pin to the tree face at DBH is measured. Compare the horizontal distance to the calculated plot radius for the tree face (DBH * PRF_f]. If the horizontal distance is within the plot radius, the tree is "in". If the horizontal distance is greater than the plot radius, the tree is "out".

Split Plots and Border Plots

In some instances it will not be appropriate to establish a full 360° plot. In these cases "split" or "border" plots must be established. The use of these plot types is to be strictly controlled by the processes outlined here (Figures 3.1 and 3.2). The only tree plots that can be split or border plots are:

- the large-tree variable-radius plot
- the large-tree fixed-radius plot

Note: The site height plots are never split.

Split Plots

The selected prism size or fixed-radius plot size may result in excessive trees to be measured at one or more plots within the cluster. It is not desirable to measure all these trees because the following may occur:

- Trees may be missed or added to the plot due to the number of measurements required, or to visibility constraints.
- Valuable crew time is expended at one location which may be better utilized on other measurements or at other locations.

Procedure

1. Estimate the number of live trees "in" with the BAF or fixed area for a full sweep around the plot. Do not make careful measurements or borderline tree checks at this time.

2. If this estimate indicates that more than 12 live trees will be "in", then split the plot using the following conventions:
   - Split the plot along the north-south cardinal bearing through the plot centre (if it is already a border plot, split it into two halves using a bearing at right angles to the polygon boundary).
   - Even numbered plot cluster = measure east half.
   - Odd numbered plot cluster = measure west half.
   - Record the plot as split on the field card.
3. Once the decision has been made to split the plot, maintain the split even if careful measurements indicate that 10 or fewer trees would have been in the original plot.

4. A sample may contain any combination of full and/or split plots.

5. Variable-radius plots will be "split" into ½ plots only.

6. Fixed-radius plots may be "split" into ½ or ¼ plots.

7. Record the azimuth of the starting point of the half or quarter sweep.

Border Plots

The plot centre and the polygon boundary may be established "close to" the adjacent polygon based on the relative size of the timber. As the vegetation inventory sampling is polygon-based, the "tree plot" measurements (whether variable or fixed) will be taken within the polygon of interest only. Top height and site plots are an exception as the plots might extend into the neighbouring polygon.

Procedure for "Half" Border Plots

1. Estimate the location of the polygon boundary.
2. Determine the azimuth of the polygon boundary.
3. Establish a line parallel to this azimuth through the plot centre.
4. Establish a half plot by using a fixed area sweep or by sweeping with the prism toward the inside of the polygon, and record all tree data for this side of the plot.
5. Record the plot as "half" on the field card.

6. Record the azimuth of the polygon boundary on the PS field card (the bearing is the start point of the sweep).

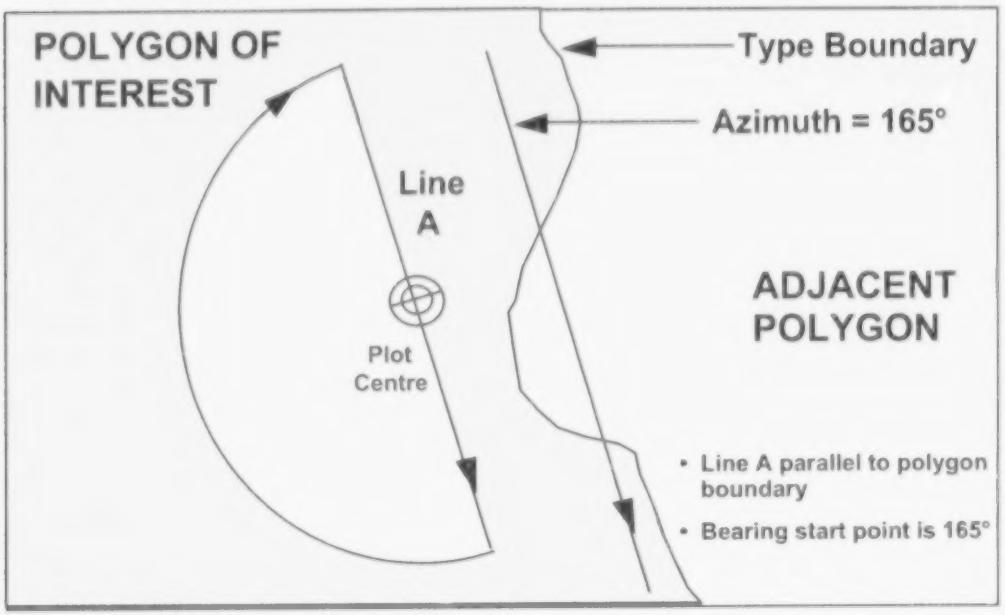

Figure 3.1: Polygon border – half plot layout.

Procedure for "Quarter" Border Plots

In some instances, the boundary of the polygon will not allow establishment of a half plot, in which case it will be necessary to establish a quarter plot.

1. Determine the location of the polygon boundary.
2. Determine the azimuth of the polygon boundary.
3. Establish a right angle quadrant within the area available for sampling.
4. Record the plot as "quarter" on the field card.
5. Record the azimuth of the polygon boundary on the PS field card (the bearing is the start point of the sweep).

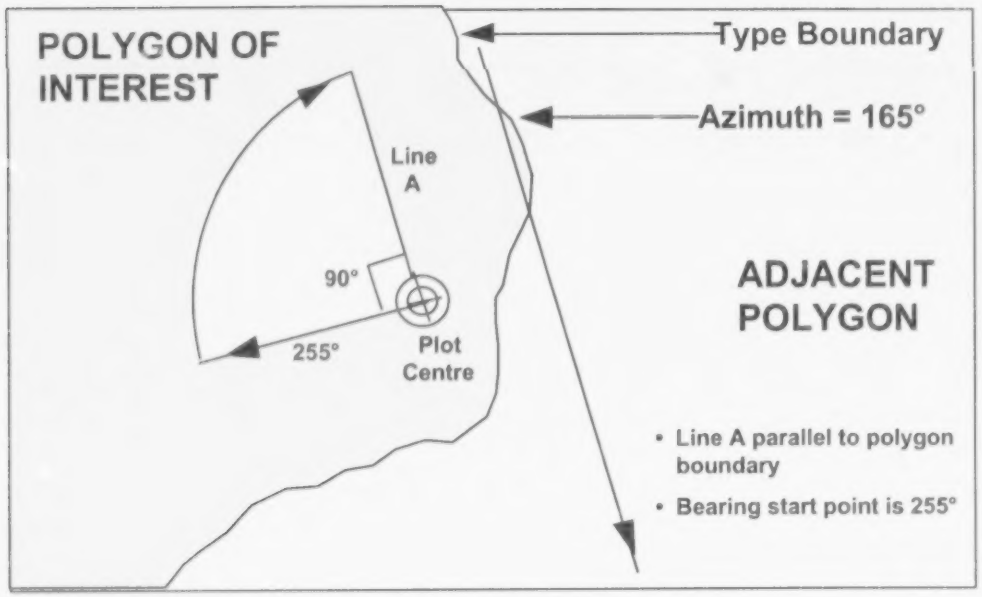

Figure 3.2: Polygon border - quarter plot layout.

3.5.3 Identifying and Recording Tree Attributes on the Full Measure Plot

Record the following measurements in the appropriate fields on the Polygon Sampling (PS) field card. The fields to be recorded are listed and described below.

For purposes of this inventory, a **tree** is defined as:

- a species identified as a tree by the botanists on this project, regardless of the size to which it does (or might) grow. Refer to Appendix D: The Vegetation Resources Inventory Tree Code List;
- longer than 1.3 m, having roots attached to the bole or an identifiable root collar; and
- greater than or equal to 4.0 cm at DBH.

Tree Number

All trees will be numbered to identify them in the field and on the field cards. The plots may be subject to audit cruising, and numbering the trees in a consistent sequence will enhance the chances of a successful remeasurement program. Trees will be marked (usually with log marking paint) in a way similar to an operational cruise plot.

Procedure

1. Start numbering the trees including borderline trees from due north of the plot centre on all plots, and proceed in a clockwise direction.
2. Mark all standing and fallen trees with painted numbers on the side facing the plot centre, if possible.
3. On trees too small to be clearly painted, put a paint dot at DBH.

4. Record trees missed on the first pass (therefore numbered out of order) on the field card (for example, "tree 9 is between 3 and 4") as a comment.
5. Paint an X on trees measured "out". Alternative marking methods may be required when it is not desirable to mark trees with paint or tags.
6. If no trees are present, put a line across the data area and record "No trees."

Tree Species

Assign a species code to all trees, measuring all trees regardless of commercial value at the time of the survey. A list of tree species recognized in the inventory is in Appendix D: The Vegetation Resources Inventory Tree Code List.

Note: It has been decided *not to measure* the willow "tree species" on the large tree WPV tree plots.

Procedure

1. Record on the field card the tree number and a species code (up to 3-characters) for the tree being measured.
2. Code all species as accurately as possible using the Vegetation Resources Inventory Tree Code List (Appendix D). If possible identify the species. If the species cannot be identified with confidence, record the genus, if known. If the genus is not known, record the appropriate code (such as Xc for an unknown conifer).

Tree Classes

Assigning tree classes allows for reporting trees in categories and reflects some potential for future growth.

Procedure

1. Record for each tree whether it is live or dead, standing or fallen.
2. Use the codes described in Table 3.2.
3. The following trees are to be recorded for WPV sampling:
   (a) live standing
   (b) live fallen
   (c) dead standing

Note: Dead fallen trees are not normally included in WPV sampling unless specifically desired by the project manager.

Table 3.2: Tree status codes.

Code		Description
Live/Dead	**L**	**Live** trees have enough foliage to keep them alive (live cambium is present), and are rooted into the ground. Lack of foliage for some species, of course, is no indication of death during some seasons.
	D	**Dead** trees are obviously dead, or roots are separated from the ground and expected to die very shortly.
Standing/ Fallen	**S**	**Standing** trees are self supporting (that is, the tree would remain standing if all supporting materials were removed).
	F	**Fallen** trees are not self-supporting.

Diameter Breast Height (DBH)

Measure and record the diameter of all live/dead, standing/fallen trees equal to or greater than 4.0 cm DBH.

Procedure

1. Determine high side ground level at the base of the tree.
2. High side is defined as the highest point of mineral soil or a humus layer around the base of the tree, no lower than the point of germination. Breast height is 1.3 m above high side measured parallel to the tree bole.
3. Measure the DBH in cm and tenths at 1.3 metres from the ground on the high side (Figure 3.3).
4. Use a stake marked at 1.3 m to accurately locate DBH on straight stems. On curved stems measure along the curve parallel to the centre of the tree.
5. Paint a line on the tree where DBH was measured, preferably facing the plot centre.
6. Record the DBH with a tight diameter tape, outside the bark, making no allowance for missing bark.
7. Record whether the DBH was measured (M) or estimated (E).

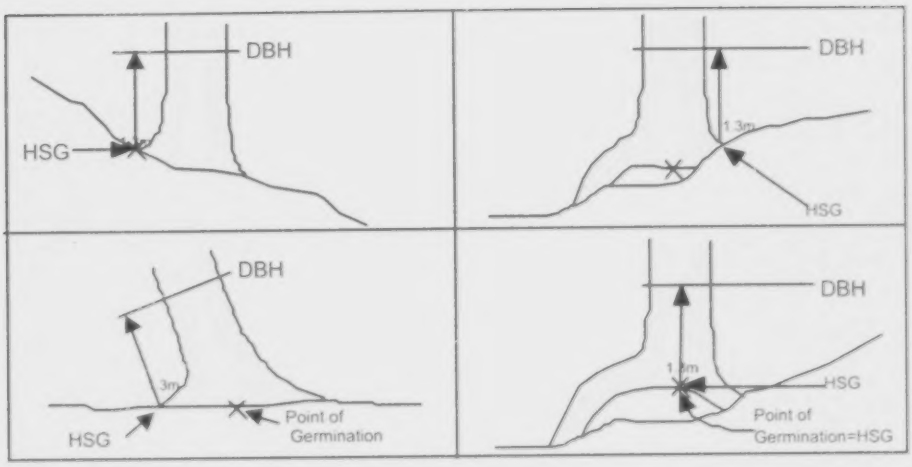

Figure 3.3: DBH in relation to high side ground (HSG) (X indicates point of germination).

Remaining Bark Percentage

The percentage of bark remaining is required to determine the actual wood volume of the tree. The impact on wood volume will be minor when small amounts of bark are missing, but could become significant when large areas of bark are missing, particularly on thick-barked species.

Procedure

1. For each DBH measurement, record the percentage of bark remaining at DBH to the nearest percent, for example:

bark: 100%	record as	- -
bark: 90%	record as	90
bark: 13%	record as	13
no bark present:	record as	00

Note: It does not matter if the diameter tape touches the exposed wood or not.

2. Calculate the bark remaining.

A simple way to obtain the percentage of bark remaining is to observe the length along the diameter tape where the bark is missing, and subtract to find the amount remaining. Calculate the percentage of bark remaining using the following formula:

$$\text{Remaining bark \%} = \left[\frac{\text{length of tape with bark}}{\text{total length of tape}} \right] * 100\%$$

See Figure 3.4 for an example.

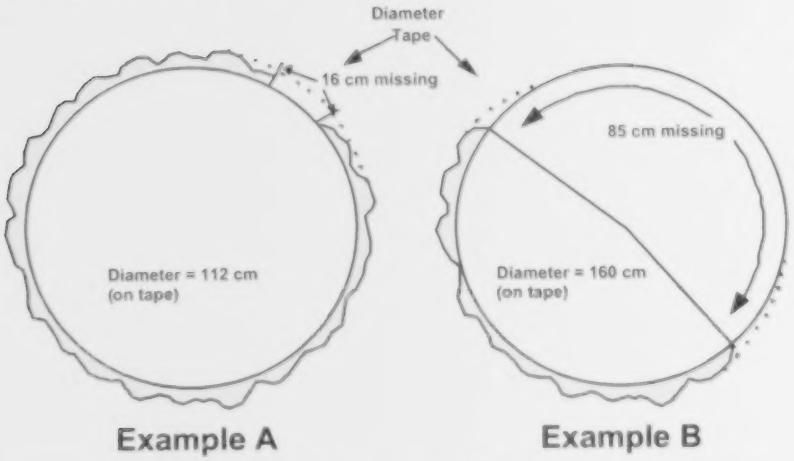

Figure 3.4: Measurement of remaining bark.

EXAMPLE A

On a 112.0 cm tree, bark is absent from 79 cm on the tape to 95 cm, a distance of 16 cm (95 – 79 = 16). The percent bark remaining is then calculated using the formula.

$$\text{Remaining bark \%} = \left[\frac{\text{length of tape with bark}}{\text{total length of tape}} \right] * 100\%$$

$$= \left[\frac{[112 - 16]}{112} \right] * 100\%$$

$$= \left[\frac{96}{112} \right] * 100\%$$

= 85.7% (Record 86%)

EXAMPLE B

On a 160.0 cm tree, bark is missing over 85.0 cm. The percent bark remaining is calculated using the formula.

$$\text{Remaining bark \%} = \left\lfloor \frac{\text{length of tape with bark}}{\text{total length of tape}} \right\rfloor * 100\%$$

$$= \left\lfloor \frac{[160 - 85]}{160} \right\rfloor * 100\%$$

$$= \left\lfloor \frac{75}{160} \right\rfloor * 100\%$$

$$= 46.9\% \text{ (Record 47\%)}$$

Tree Length

Measure the length of each tree within the full measure plot, including broken trees.

Measure all trees except where the measurement is physically obstructed, it is unsafe to make the measurement, or when an accurate measurement is impossible. In such cases estimate the tree length.

For trees with broken tops, see discussion of Broken Tops below. For odd-shaped trees see Figure 3.5.

Procedure

1. Estimate the tree length before measuring as a check on your calculations.
2. Measure the length of the tree from the ground level on the high side along the stem to the top of the stem. Record length to the nearest 0.1 m.
3. For broken stems, measure the length that allows the most appropriate application of taper functions for calculating the volume of the tree. See the following section on the measurement of broken top trees.
4. For fallen broken trees, record the length of the stem to the break. Measure the portion of the tree from the root collar to the top of the last connected portion (the pieces must be physically attached so that if one part is moved the next part will move).
5. Record whether the length was measured (M) or estimated (E).

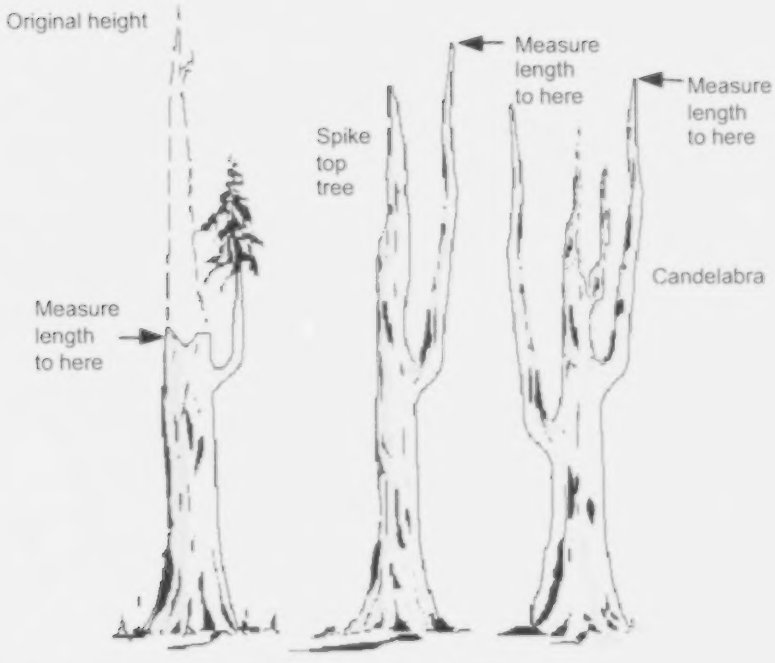

Figure 3.5: Measurement of odd-shaped trees.

Broken Tops

Measure all broken trees to the location of the broken top. For the compilation program to apply appropriate form factors to the tree stem, the diameter at the breakage point **OR** the original (projected) length of the potential tree must be recorded. If the broken top is available on the ground then a direct measure of diameter or actual "projected" height may be possible to measure.

Procedure

1. Measure the length of the tree stem to the break. For shattered stems, estimate the length after folding in shattered wood to make a whole diameter.
2. Choose one of the following options, depending on which can be most reliably estimated:
   - estimate the diameter of the stem at the break
   - estimate the original unbroken height of the tree
3. Record the broken top diameter (in cm) or the projected height (in m) on the field card. All trees with broken tops must have only **one** of these fields completed.

3.5.4 Recording Age/Height [Length] Tree Data

Age/height tree data is recorded on the Polygon Site Tree Data field card (PT).

Objective

Age/height trees are measured to determine age and height for the top height, leading and second species in the cluster and to determine site index.

General Procedures

The following types of trees are measured for age and height (length):

Standard selection types:

Top height	(Type = **T**)	Largest DBH in 0.01 ha plot, of any species on the individual plot
Leading species	(Type = **L**)	largest DBH in 0.01 ha plot, of leading species on the individual plot
Second species	(Type = **S**)	largest DBH in 0.01 ha plot, of second species on the individual plot

The T, L and S trees are selected and measured at the full measure plots only, when employing the "full measure / count plot" method. If the "distributed measure tree " method is employed all plots are potentially measure plots. The objective is to select a non-biased complement of age and site index data across the polygon. Therefore at each plot select the top height tree. If the selected tree is also the leading or second leading species on the plot record the tree in the appropriate category with the type "L" or "S" code.

The leading species and second species are determined from the stem count of the **live** trees tallied at the individual full measure plot. If partial plots are used, then the count is based on the established portion of the plot. The selection of the leading and second leading site trees will be measured on the full 5.64 metre (0.01 ha, plot). In the case of a tie between two species, the species with the largest average diameter will be chosen.

The following criteria are used to select **T**, **L** and **S** trees:

- within the 0.01 ha plot (5.64 m),
- largest DBH tree,
- must be alive,
- dominant or co-dominant,
- species (for L and S trees only).

T, L and **S** trees are selected from all living trees within a 5.64 m radius of plot centre; dead trees are not taken into account. If any potential **L** or **S** tree meets the above criteria, the age and height **must** be measured and recorded on the field card. The following figure shows how the information is recorded (Figure 3.6).

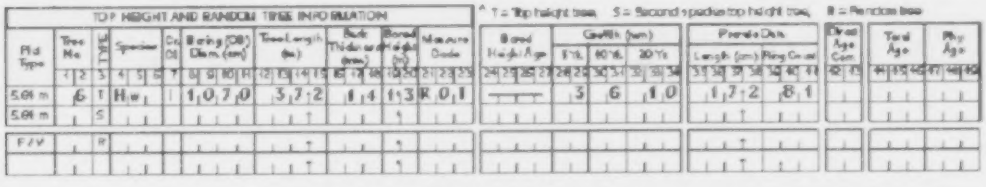

Figure 3.6: Recording of height and age information on the PT field card.

Non-standard selection types:

- Other (Type = O) an alternate tree in 0.01 ha plot
- X extra (Type = X) an alternate tree outside 0.01 ha plot

These **additional** trees may be selected in a non-standard manner at the discretion of the field crew. This flexibility is provided for special cases where the field crew feels that adequate information cannot be provided following the standard procedure alone. For example, the cluster is located in a patch of recently killed trees or a tree is unsafe to measure. For this to be of any practical use, comments must be supplied to explain why the tree was selected.

Suitability of Age and Height

A tree may meet the above selection criteria and still not provide a suitable age and/or height. **The age and height are still recorded in these instances with an "N" placed in the appropriate column.** An explanation must be given in the comments section as to why the age and/or height are not suitable.

The S/H (suitable for height) and S/A (suitable for age) columns are to be filled out for all L, S and T trees selected. These columns indicate whether the age or height is suitable to be used in compiling age, height and site index for the sample. In these columns, a "Y" means the item is suitable and an "N" means it is not suitable.

The age and height data may also be used for special purposes, such as ecological correlation studies. These studies may require additional screening for tree suitability. The screening will rely on the physiological age values, age prorate information and additional crew comments to screen trees with rot or suppression or other damage.

Examples of reasons for a tree not being suitable for height:

- significant broken top (projected length is recorded for broken top trees),
- significant dead top,
- fork or crook that significantly affects height growth,
- abnormally high amount of scarring or other damage that may have affected height growth (for example, significant mistletoe infection).

Note: *Significant* refers to a reduction in the length of the tree compared to what it would be if undamaged. The reduction is great enough that a reliable site index estimate could not be obtained from the tree measurements.

The only reason for a tree not being suitable for age:

- residual (definition follows)

  A *residual* tree is defined as a living remnant of a former stand; in even-aged stands, the occasional (< 25 per ha) large stem of an older age class than the stand as a whole.

  Typically, these trees may have larger diameters, a higher incidence or indications of decay, thicker bark, larger branching and "ragged" or flat tops. These trees must be clearly residual. Uneven-aged stands do not generally have residual trees.

Procedure for Selecting Leading Species and Second Species Trees Using the "Full Measure/Count Plot" Method

The procedure outlined in this section describes the methods used to select and measure age/height trees when employing the full measure count plot method.

1. Complete the full measure sample plot using standard procedures.

2. Determine the leading and second species by basal area for the plot using the tree count information.
3. Establish a 0.01 hectare plot (5.64 m radius) at the plot centre(s).
4. Select age/height trees in the 0.01 ha plot as follows:
   (a) At the Full Measure plot centre:
   - largest DBH, live, dominant or co-dominant tree of any species (**T** tree)
   - largest DBH, live, dominant or co-dominant tree of leading species (**L** tree),
   - largest DBH, live, dominant or co-dominant tree of second species (**S** tree).
5. Select additional dominant and co-dominant trees (if applicable):
   - Other tree in 0.01 plot (O tree),
   - Extra tree outside 0.01 plot (X tree).
6. Measure and record tree height for each selected tree.
   - Determine suitability for height and enter code in S/H column.
7. Measure age and radial increment for each selected tree.
   - Determine suitability for age and enter code in S/A column.

Procedure for Selecting Leading Species and Second Species Trees using the "Distributed measure tree plot" method

The procedure outlined in this section describes the methods used to select and measure age/height trees when employing the distributed measure tree method.

1. Complete the full measure sample plot using standard procedures.
2. Determine the leading and second species by basal area for the plot using the tree count information.
3. Establish a 0.01 hectare plot (5.64 m radius) at the plot centre(s).
4. Select age/height trees in the 0.01 ha plot as follows:
   (a) At the Full Measure plot centre:
   - Largest DBH, live, dominant or co-dominant tree of any species (T tree)

   (b) Identify if the "T" tree selected is either the largest DBH, live, dominant or co-dominant tree of leading species (L tree), or the largest DBH, live, dominant or co-dominant tree of second species (S tree). Record on the field record the appropriate code of "L" or "S".
5. Select additional dominant and co-dominant trees (if applicable):
   - Other tree in 0.01 plot (O tree),
   - Extra tree outside 0.01 plot (X tree).
6. Measure and record tree height for each selected tree.
   - Determine suitability for height and enter code in S/H column.
7. Measure age and radial increment for each selected tree.
   - Determine suitability for age and enter code in S/A column.

Crown Class

Crown class is a ranking, by crown position, of a tree in relation to other trees in the immediate area surrounding the tree being measured. The crown class will be useful in future growth models.

Procedure

1. Assign a crown class code to all the selected site trees using the descriptions in Table 3.3.
2. Dead trees and fallen live trees will **not** have a crown class assigned, mark a dash through the field card boxes.

Table 3.3: Crown class codes.

Code	Description
D	**Dominant** Trees with crowns that extend above the general level of the trees immediately around the measured trees. They are somewhat taller than the codominant trees, and have well-developed crowns, which may be somewhat crowded on the sides, receiving full light from above and partly from the side.
C	**Codominant** Trees with crowns forming the general level of the trees immediately around the measured trees. The crown is generally smaller than those of the dominant trees and is usually more crowded on the sides, receiving full light from above and little from the sides.
I	**Intermediate** Trees with crowns below, but extending into, the general level of the trees immediately around the measured trees. The crowns are usually small and quite crowded on the sides, receiving little direct light from above but none from the sides.
S	**Suppressed** Trees with crowns entirely below the general level of the trees around the measured trees, receiving no direct light either from above or from the sides.

Measuring Height, Age and Growth Information

Age is an important measurement in cruising because it helps in determining the site index and projected rate of growth. In each measure plot site tree(s) will be bored to determine age.

Procedure for Direct Measurement of DBH Age

1. Count the whorls above DBH and add one to calculate the age of the tree.
   - Enter the code WHO.
   - Record the age.
2. Rather than damaging a small tree on the plot, select a tree of similar apparent age from outside the plot. This would frequently happen with trees of less than 2 m in length. The replacement tree should be outside the 10 m fixed-radius plot, if possible. Determine the DBH age by cutting or boring.
   - Enter the code OUT.
   - Record the length and diameter for the originally selected top height tree, but record the age from the tree selected from outside the plot.
3. In instances where trees do not reach DBH, use either of the above procedures, as appropriate.
   - Enter the code as appropriate (WHO or OUT).

- Record the total age for the tree.
- Record bored height as 0.0.

Procedure for Measuring Age on Bored Trees

1. Bore the tree at DBH facing plot centre, if possible. If DBH cannot be bored conveniently, record the height of boring; corrections will be made later.

2. Determine the age by a ring count from an increment borer core, if possible, and enter the data in the **field count** section on the tally card. The count will be the number of full rings. It is up to the field crew to determine when diameter growth has essentially stopped for the season.

3. The pith should be included in sample tree cores as often as possible to ensure accuracy, particularly in stands less than 80 years old. If you can get within a few years of the pith (relative to the tree age) and can confidently estimate the remainder, there is no need to rebore the tree or use a "physiological" age calculation. Record the actual age at the level where the tree was bored. Adjustments for years to reach that point will be done in the office compilation.

Note: In all cases of top height trees, the length of the sample tree to an unbroken top must be available since this data is used for site index calculations. **On a tree with a small break at the top, always estimate the height to an unbroken top**.

---

4. On large trees, or trees that have rotten centres, record the code for rot, age of the sound portion, and the length of sound core. The computer will calculate an approximate age using these measurements. Be careful to measure only inside bark length along the core.

Note: Age relationships can also be derived from actual stump counts if working near felled road rights-of-way or logged areas.

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5. Collect all tree cores in labeled "straws" and return to the field office.
   - It is the crew's responsibility to accurately record field age data. The initial determination will be made in the field and confirmed in the field office based on the straw samples.
   - The project manager will have the microscope age counts entered in the "office" count sections on the field cards.
   - Record at least the following on the straw in waterproof felt marker or on attached labels: polygon number, plot number, tree type (L, S,) and tree number (for example, Polygon 273, Plot 7, L tree # 3).

Procedure for Measuring Radial Increments (Optional)

1. Make radial increment measurements on all trees counted for age at the same level on the stem.
2. Bore on the side facing the plot centre, at DBH if possible.
3. When it is not practical to take the increment in this direction, take it at two points at right angles on the bole of the tree (at the same height as the age boring) and average them.
4. Record the radial increment (in mm) for 5, 10 and 20 years using full rings.

Procedure for Measuring Physiological Age

1. If a sample tree for age measurement was suppressed in its early years, record the unsuppressed (physiological) age as calculated for that tree. The intent is to give an age that would be typical for the tree size if the tree had not undergone unusual suppression (or, more rarely, unusual growth).
2. Determine the physiological age as follows:
   - Enter the PHY code to indicate that a physiological age is used. The computer will calculate the age for you if you have not entered the age yourself.
   - For small trees, where you can interpolate accurately across the suppressed section, simply count "equivalent" rings.
   - For larger trees, particularly where centre sections are missing, leave the boring height age blank, and:
     - Count the number of years along the section closest to the bark. As with small trees, account for any clearly atypical growth sections by interpolation.
     - Enter the length of the core over which you have counted the partial age. The computer will use this data to calculate the "missing rings."
     - If you have a good estimate of the tree age it would also be useful to have that in the notes section.

Recording Height, Age, and Growth Information

See Section 3.5.3, "Identifying and Recording Tree Attributes," for a complete description of codes. The following details are recorded on the PT field card:

Tree No.	Tree number as recorded in tree measurement plot. If not present in the tree measurement plot, assign a number (99, 98...) to indicate that it is "not in the large tree plot".
Type	T = top height tree, L = Leading species tree, S = second species tree.
Species	Tree species code.
Crown Class (C.Cl.)	Record crown class code (D, C, I, S).
Boring (OB) Diameter (cm)	Diameter outside bark at location of increment boring.
Tree Length (m)	Measured length of the tree to 0.1 m.
Suitable Height	Record a "Y" for "yes" if the tree height has not been significantly affected and is suitable for calculating a reliable site index estimate. Record a "N" for "no" if the tree height has been significantly affected.
Bark Thickness (mm)	"Single Bark" thickness at location of boring(s). **Not collected for WPV sampling.**
Bored Height (m)	Height (above high side ground level) where boring was made.
Measure Code	If the crew did not physically measure to the pith, this code indicates the reason. Acceptable codes are:
	ROT = Core of tree rotten or missing.
	WHO = Total age determined from whorl count rather than boring.
	CRC = Increment borer cannot reach centre (tree too large).
	OUT = Age and radial increments determined from similar tree outside of plot, all other measurements for the tree within the plot.
	PHY = Physiological age is recorded or calculated on that tree. Usually due to atypical growth ring patterns.
Field Age Count	Repeat the Tree No. For each type, and record the actual age (number of rings) at boring height in the lower-left corner of the card.
Office Bored height age	Increment cores are recounted in the office under magnification. Enter the recounted age in this data field.
Growth (mm)	Growth for last 5, 10 and 20 years.
Prorate Data	When a full boring is not possible record the actual measurements.
• **Length (cm)**	Length of increment core, from outer edge inward, upon which the ring count was made.
• **Ring Count**	Actual or representative count of tree rings along that core length.
Direct Age Correction	Number of full years of tree growth below the boring height, if it can be determined directly on that tree.
Physiological Age	Physiological age at the bored height determined by the crew. Record PHY in "Measure Code" field. It is not always necessary to enter this information.
Suitable Age	If the tree is a "Residual" then the tree is recorded as "N" for "not" suitable. All other trees are recorded as "Y" for "yes" as suitable for age.

Examples of Recording Age Information

Normal tree where the increment borer can reach the tree pith (enter - - - in the Measure Code field)

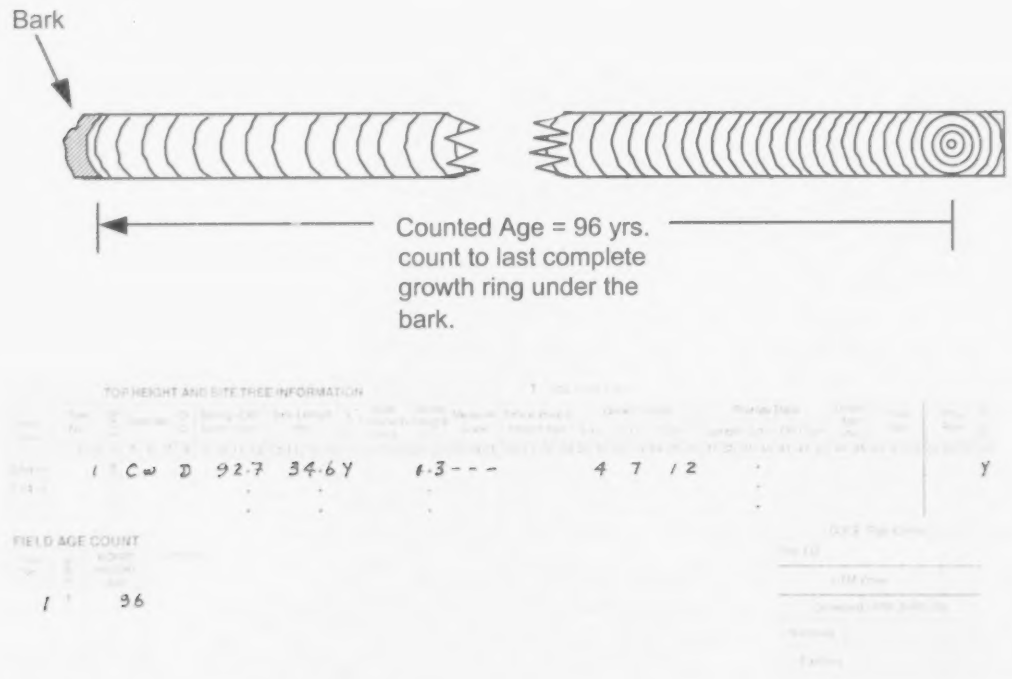
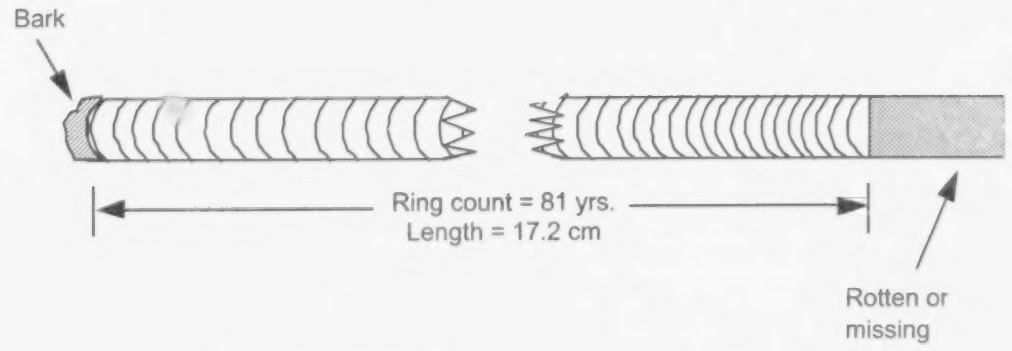

Bark
Counted Age = 96 yrs.
count to last complete
growth ring under the
bark.
TOP HEIGHT AND SITE TREE INFORMATION
1 Cw D 92.7 34.6Y 1.3- - - 4 7 12 Y
FIELD AGE COUNT
1 96

Figure 3.7: Recording age for full boring.

Tree with rotten or missing core (ROT)



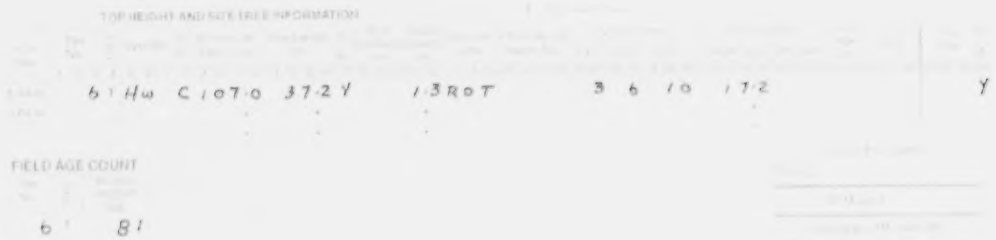


Figure 3.8: Recording age for tree with missing core (ROT).

Trees where increment borer cannot reach centre of the tree (CRC)

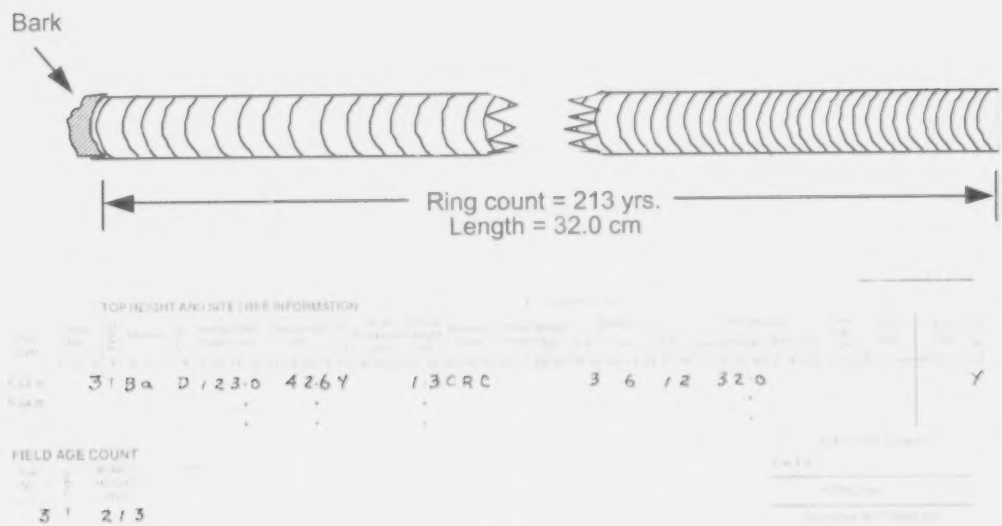

Bark
Ring count = 213 yrs.
Length = 32.0 cm
TOP HEIGHT AND SITE TREE INFORMATION
3 1 Ba D 123.0 42.6 Y 1.3 CRC 3 6 12 32.0 Y
FIELD AGE COUNT
3 1 213

Figure 3.9: Recording for partial boring (CRC)

Out-of-plot tree taken for sample age (OUT)

If the selected sample trees are too small to be bored without damaging the tree, or the length of the plot tree is less than 2 m, a representative tree of the same species from outside the plot (outside the 10.0 m plot at the integrated plot centre) can be cut down and counted, or bored. The preference in young stands (less than 2 m in height) would be to count the age as close as practical to the ground.

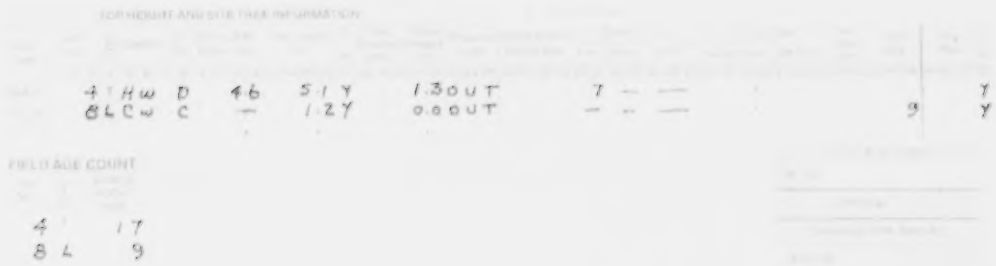
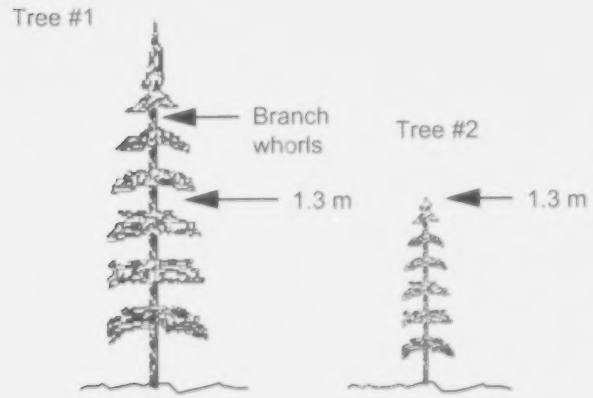


Figure 3.10: Recording age for out-of-plot-tree.

Tree age determined directly from count of branch whorls (WHO)



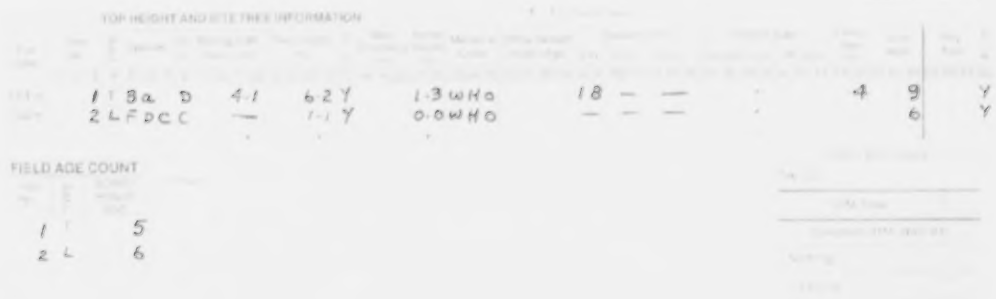


Figure 3.11: Recording age using whorl count.

Physiological Age Measurement (code as PHY)

Calculation of Physiological Age:

1. Non-suppressed growth rate (47 years ÷ 20.0 cm = 2.35 years/cm)
2. Physiological age (2.35 years/cm X 25.0 cm = 59 years)

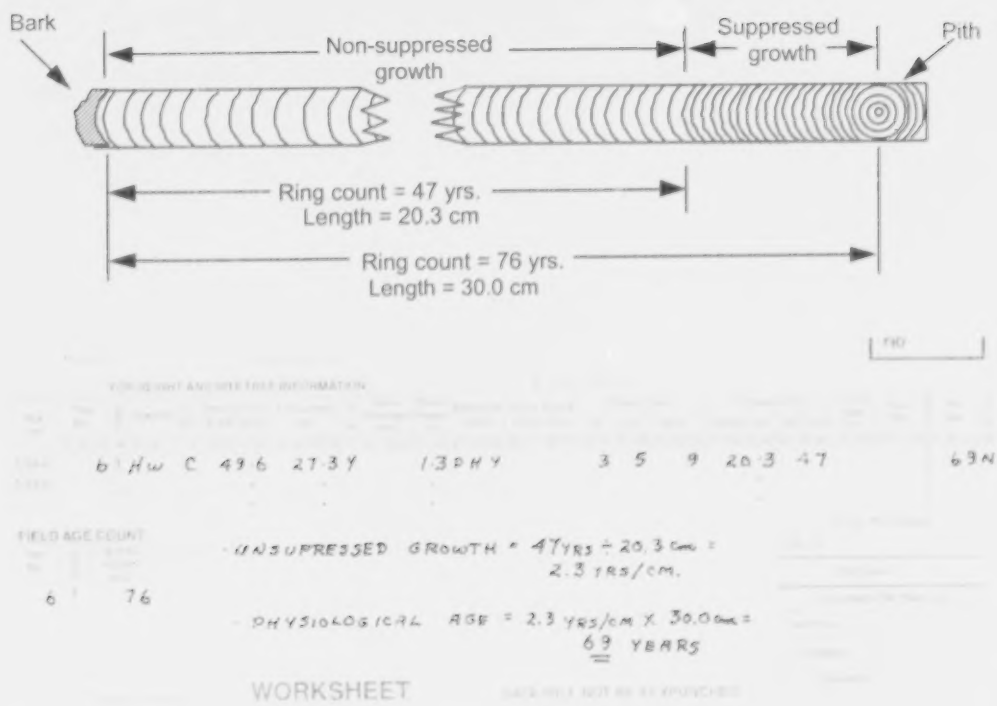

Bark
Non-suppressed growth
Suppressed growth
Pith
Ring count = 47 yrs.
Length = 20.3 cm
Ring count = 76 yrs.
Length = 30.0 cm
UNSUPRESSED GROWTH = 47YRS ÷ 20.3 cm = 2.3 YRS/CM.
PHYSIOLOGICAL AGE = 2.3 YRS/CM X 30.0 cm = 69 YEARS
WORKSHEET

Figure 3.12: Recording physiological age.

3.5.5 Recording Count Plot Measurements

The count plots will be used to supplement the information collected on the full measure plots. Record the data on the polygon sampling (PS) field card.

Record the following data on a variable-radius plot (or 5.64 m fixed-radius plot) for live standing, live fallen and dead standing trees 4.0 cm DBH and larger:

- tree number
- tree species
- live trees (record L), dead trees (record D)
- standing trees (record S), fallen live trees (record F)
- tree diameter (DBH)

New Species and Additional Data (if needed)

When a "new tree species" is first encountered, randomly select the new species tree from the sample trees on that plot (referred to as an "insurance" tree). For live or dead standing trees that are a new species (not measured on any full measured plot, take the same measurements as on the full measure trees. "Enhancement" is the common term used to describe the process where detailed measurements are taken on the selected tree. If the tree species is encountered on a future full measure plot, then the full measure data for the "insurance" tree is to be deleted.

Note: The intent is to have **live** and **dead** measured sample trees **for all species** in order to calculate volume to basal area ratio (V-BAR) values.

3.5.6 Collection of GPS Data Records

A field has been created on the Polygon Site Tree Data field card (PT) for the collection of GPS point data. If GPS data is collected it is recommended to collect data at opposite edges of the polygon in order to orientate the final plot locations in the polygon.

Appendix A: Use of WPV data

The following is based on a discussion paper prepared for the Vegetation Inventory Working Group titled, *The "Error" of the New Vegetation Inventory. What does that mean* by Kim Iles. This paper is available from the MSRM Terrestrial Information Branch in Victoria.

Within-polygon variation data can be used for two main purposes:[1]

1. Estimate *process (actual) error* – the difference between actual polygon value and the adjusted polygon value. This information expresses the "true" variability of the adjusted polygon values, and it can be used to evaluate the relative efficiency of the regression adjustment method (and the Estimation Phase).
2. Estimate the apparent *polygon error* – the percentage difference between observed polygon value (based on a sample of one or more plot clusters in a polygon) and the adjusted polygon value. This information can be used to state the expected error rate of individual polygons in an inventory unit.

Process Error

Overall error is normally calculated for an inventory unit. This overall error (or precision) is usually expressed as sampling error. Sampling error is obtained by dividing the standard deviation for inventory unit by the square root of the sample size (typically 50-200). It will generally be relatively small for the inventory unit as a whole.

The question is: *What is the true standard deviation for polygon values which we should be using to calculate sampling error*? The variability that we should be using is the one based on process error, which is the difference between the actual polygon value versus the adjusted value. It is not the variability based on the one (or a small number) of *clusters* in a polygon versus the adjusted value. This latter variability inflates the apparent standard deviation because of the "polygon error", which is the uncertainty about the polygon value that is being compared to the adjusted value. This inflation greatly reduces the calculated efficiency of the regression adjustment method. That is, it would greatly undervalue the relative efficiency provided by the Estimation Phase.

WPV sampling, because it involves many measurements, provides data to estimate the "true" values for a number of polygons. This data can then be used to calculate the appropriate standard deviation.

Boston Bar Example. This example is taken from the MOF report *Vegetation Resources Inventory. Report on the 1995 Boston Bar Operational Trial: Polygon areas and timber volume results*. Twelve polygons out of the 143 that were sampled as part of the regular Ground Sampling Phase were intensively sampled for tree attributes with a total 32 plots in each polygon. This is about six times as many plots as the usual Ground Sampling Phase, single cluster per polygon. Adjusted values were calculated for each polygon based on the regression established between the ground observations using a single cluster and the Estimation Phase estimates.

---

[1] There may be other uses of WPV data that are not identified in this report.

The relative difference between the polygon adjusted volume (based on the regression) and the "true" volume (based on intensive sampling) was 34%, that between the adjusted values and the observed volume based on a single cluster was 56%, and that of the intensive ground samples alone was 72%. In this example, the estimated process error is 34%. That is, volume estimation using the Estimation Phase estimates is about four times ($72\%^2/34\%^2$) more efficient than using ground samples alone.

Polygon Error

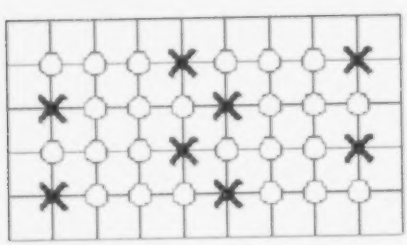
WPV data is also used to give users a reasonable expectation of the difference they should expect to find when they "check the timber inventory" in the field using a reasonable number of observations.

If the user checked the database answers against a sample of the inventory polygons and found the expected error, then they might be more inclined to accept the inventory results. We would surely want to give some indication that installing just a few plots and comparing them to the database values will not *seem* to indicate the accuracy we have claimed, but this is the fault of the user for not knowing the correct polygon value. Note that the observed polygon value from WPV sampling is not the "true" values, which we would prefer, but only an *estimate* of that value which would get better as we take more samples within the polygon. As sample size increases, we expect the difference between the estimate and the 'true' value to vanish.

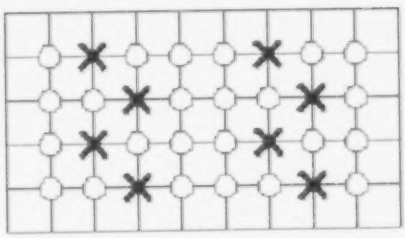
The expected rate of error for individual polygons for continuous variables can be stated for the inventory unit. In addition, the extra rate of error for installing one, two or any number of plots, can be given to the user. If polygons are "checked" with some number of plots this additional error estimate will give the user a realistic idea of how close their estimate should be. In the case of categorical variables, all we can hope to do is to demonstrate the number of times an item will fall into a particular incorrect category. This is called an "Error Matrix".

The **Boston Bar example** results indicated that if the user checked the inventory using a sample of 12 polygons and the 32-plot method, they would expect a relative difference of 34 %; if they used only one cluster, they would expect a relative difference of 56 %. The Boston Bar data also indicated that the adjusted volumes of 7 out of the 12 intensively sampled polygons were within the confidence interval of the average based on the intensively sampled polygons. This means that if a user visited a polygon at random and measured the volume using the 32-plot method, there is roughly a 58% chance that they would find the same volume depicted in the database.

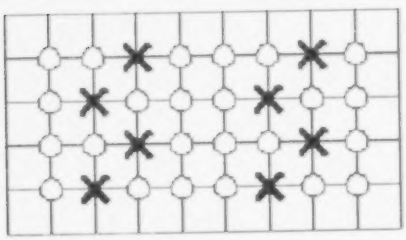
Appendix B: Sample Grid Patterns



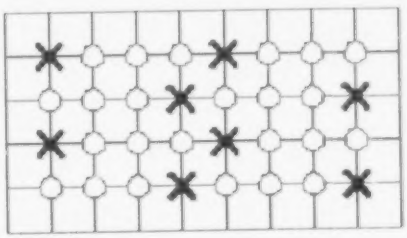
1



3



2



4

X = full measure plot

○ = count plot

The above are sample patterns that can be used to distribute the full measure plots. In all these patterns, there are 8 full measure plots and 24 count plots. Other patterns may be designed by the project manager ahead of time. One of the patterns is randomly chosen by the project manager. An additional option is to establish a systematic grid of count and measure plots from a random start inside the polygon.

Appendix C: "PPSWR" Process

A detailed description of the selection methodology is available on the Ministry website entitled " Sample Selection Procedures for Ground Sampling".

Land Cover Categories

Pre-stratification is a requirement of the probability proportional to size with replacement (PPSWR) sampling strategy. With pre-stratification, PPSWR is more efficient than simple random sampling. For most inventory units in B.C., it is recommended that the photo-interpreted polygons be separated by the following domains or categories:

a) non-vegetated,

b) vegetated non-treed, and

c) vegetated treed polygons.

The non-vegetated polygons include lakes, rock, bare ground and double line roads which have no vegetation cover. The application of PPSWR in this category does not require further sub-stratification.

The vegetated non-treed category consists of polygons with vegetation but with no trees. Where trees do exist, they constitute less than 10% of the vegetation crown closure. As in the case for the non-vegetated category, further sub-stratification is not required for the application of PPSWR.

In situations where full VRI sample selection is required, where all the three land cover categories should be sampled, the full VRI sample can be allocated proportionally to the three domains.

Vegetated Treed Category

The vegetated treed category consists of polygons with forest cover on them. By definition treed polygons have 10% tree crown closure or greater. For timber emphasis plots (TEPs), all the samples will be within the vegetated treed category.

The application of PPSWR in this category requires further sub-stratification, and should be carried out as follows:

1. **Separate the polygons by strata.**

   Review the stratification criteria to ensure that polygons are classified in the appropriate categories. Strata will typically be defined by leading species, or species groups, and then further stratified by three or four volume classes, or appropriate surrogates. For example, the landbase may be stratified into 4 leading species groups, or based on a combination of leading species and growth or economic characteristics.

   It is recommended that the number of strata be restricted to range between 2 and 6, as the benefits of stratification are lost if too many strata are created. Also, when a minimum sample size is required for the smallest stratum, sample size may increase substantially as the number of strata increase.

2. **Separate the strata into sub-strata.**

   For convenience and to insure an even distribution of samples across stratum, we recommend creating 3 equal sub-strata based on the number of polygons. The attribute on which the sub-stratification should be based is volume, however, in the absence of volume, a surrogate attribute such as basal area can be used.

3. **Determine the sample allocation (number of sampling points) for each stratum and sub-strata within the stratum.**

   This information is usually partially specified in the VRI Strategic Inventory Plan. Currently, a minimum sample size of 15 samples per stratum is recommended, based on requirements for sequential balancing by strata.

4. **Determine the total area for each stratum, and sub-strata within a stratum.**

   The sub-strata should be designed to result in sub-groupings (within a stratum) with approximately an equal number of polygons. Allocation of samples to sub-strata should be proportional to total area of each sub-stratum.

5. **Accumulate the individual polygon areas beginning with the first polygon in the sub-stratum to the last polygon in each sub-stratum.**

   These accumulated areas should be stored as a new attribute, as they are used in selecting the sample.

6. **Generate as many random numbers as there are allocated samples for each sub-stratum.**

   The random numbers should be generated separately for each sub-stratum, and should range in size between 0 and the total area of each sub-stratum.

7. **Use the generated random numbers to identify the sample polygons.**

   A polygon is selected if a generated random number is larger than the accumulated total area corresponding to the polygon immediately preceding it, and the random number is smaller than or equal to its accumulated area.

8. **A polygon may be selected more than once.**

   After the first selection, the polygon is retained in the list and is eligible for any subsequent selection. The number of sample clusters that are established in a sample polygon should be equal to the number of times the polygon was selected during the selection process.

   Additional sample polygons (e.g., 50% per stratum) may be drawn and archived for future use.

   The mechanics of the sample selection process will be unique to each project, therefore, it would be advisable to check with a consulting biometrician or the Terrestrial Information Branch mensurationist for consistency.

Appendix D: The Vegetation Resources Inventory Tree Code List

Version 4.3 — March 2002
Data Custodian: Director, Research Branch, B.C. Ministry of Forests

This section lists the common name, scientific name, and tree code for B.C. trees. Trees are defined as being woody, single stemmed, and capable of growing to greater than 10 m in height.

For the latest tree code listing see http://www.for.gov.bc/research/pubs/1188.htm

* = Introduced species not known to occur on Crown Land but requiring a code for database purposes.

Native Conifers

Common name	Scientific Name	Code
Cedar	***Thuja***	**C**
western redcedar	*Thuja plicata*	Cw
Cypress	***Chamaecyparis***	**Y**
yellow-cedar	*C. nootkatensis*	Yc
Douglas-fir	***Pseudotsuga***	**F**
Douglas-fir	*P. menziesii*	Fd
coastal Douglas-fir	*P. menziesii* var. *menziesii*	Fdc
interior Douglas-fir	*P. menziesii* var. *glauca*	Fdi
Fir (Balsam)	***Abies***	**B**
amabilis fir	*A. amabilis*	Ba
grand fir	*A. grandis*	Bg
subalpine fir	*A lasiocarpa*	Bl
Hemlock	***Tsuga***	**H**
mountain hemlock	*T. mertensiana*	Hm
western hemlock	*T. heterophylla*	Hw
mountain x western hemlock hybrid	*T. mertensiana* x *heterophylla*	Hxm
Juniper	***Juniperus***	**J**
Rocky Mtn. juniper	*J. scopulorum*	Jr
Larch	***Larix***	**L**
alpine larch	*L. lyallii*	La
tamarack	*L. laricina*	Lt
western larch	*L. occidentalis*	Lw

Common name	Scientific Name	Code
Pine	***Pinus***	**P**
jack pine	*P. banksiana*	Pj
limber pine	*P. flexilis*	Pf
lodgepole pine	*P. contorta*	Pl
lodgepole pine	*P. contorta* var. *latifolia*	Pli
lodgepole x jack pine hybrid	*P.* x *murraybanksiana*	Pxj
ponderosa pine	*P. ponderosa*	Py
shore pine	*P. contorta* var. *contorta*	Plc
western white pine	*P. monticola*	Pw
whitebark pine	*P. albicaulis*	Pa
Spruce	***Picea***	**S**
black spruce	*P. mariana*	Sb
Engelmann spruce	*P. engelmannii*	Se
Sitka spruce	*P. sitchensis*	Ss
white spruce	*P. glauca*	Sw
spruce hybrid	*Picea* cross	Sx
Engelmann x white	*P. engelmannii* x *glauca*	Sxw
Sitka x white	*P.* x *lutzii*	Sxl
Sitka x unknown hybrid	*P. sitchensis* x *?*	Sxs
Yew	***Taxus***	**T**
western yew	*Taxus brevifolia*	Tw

Native Hardwoods

Common name	Scientific Name	Code
Alder	***Alnus***	**D**
red alder	*A. rubra*	Dr
Apple	***Malus***	**U**
Pacific crab apple	*Malus fusca*	Up
Aspen, Cottonwood or Poplar	***Populus***	**A**
poplar	*P. balsamifera*	Ac
balsam poplar	*P. b.* ssp. *balsamifera*	Acb
black cottonwood	*P. b.* ssp. *trichocarpa*	Act
hybrid poplars	*P.* spp.	Ax
trembling aspen	*P. tremuloides*	At
Arbutus	***Arbutus***	**R**
Arbutus	*Arbutus menziesii*	Ra

Common name	Scientific Name	Code
Birch	***Betula***	**E**
Alaska paper birch	*B. neoalaskana*	Ea
Alaska x paper birch hybrid	*B.* x *winteri*	Exp
paper birch	*B. papyrifera*	Ep
water birch	*B. occidentalis*	Ew
Cascara	***Rhamnus***	**K**
cascara	*R. purshiana*	Kc
Cherry	***Prunus***	**V**
bitter cherry	*P. emarginata*	Vb
choke cherry	*P. virginiana*	Vv
pin cherry	*P. pensylvanica*	Vp
Dogwood	***Cornus***	**G**
Pacific dogwood	*Cornus nuttallii*	Gp
Maple	***Acer***	**M**
bigleaf maple	*A. macrophyllum*	Mb
vine maple	*A. circinatum*	Mv
Oak	***Quercus***	**Q**
Garry oak	*Q. garryana*	Qg
Willow	***Salix*** spp.	**W**
Bebb's willow	*S. bebbiana*	Wb
Pacific willow	*S. lucida*	Wp
peachleaf willow	*S. amygdaloides*	Wa
pussy willow	*S. discolor*	Wd
Scouler's willow	*S. scouleriana*	Ws
Sitka willow	*S. sitchensis*	Wt

Unknowns

Common name	Scientific Name	Code
Unknown		**X**
Unknown conifer		Xc
Unknown hardwood		Xh

Others

Common name	Scientific Name	Code
Other tree, not on list		**Z**
Other conifer		Zc
Other hardwood		Zh

Exotics

Common name	Scientific Name	Code
Apple	**Malus**	**U**
apple	*Malus pumila*	Ua
Aspen, Cottonwood or Poplar	***Populus***	**A**
*southern cottonwood	*P. deltoides*	Ad
Birch	***Betula***	**E**
European birch	*B. pendula*	Ee
silver birch	*B. pubescens*	Es
*yellow birch	*B. alleghaniensis*	Ey
Cherry	***Prunus***	**V**
sweet cherry	*P. avium*	Vs
Cypress	***Chamaecyparis***	**Y**
*Port Orford-cedar	*C. lawsoniana*	Yp
Fir (Balsam)	***Abies***	**B**
*balsam fir	A. balsamea	Bb
noble fir	A. procera	Bp
*Shasta red fir	**A. magnifica var. shastensis**	Bm
*white fir	**A. concolor**	Bc
Larch	***Larix***	**L**
*Dahurian larch	*L. gmelinii*	Ld
Maple	***Acer***	**M**
box elder	*A. negundo*	Me
*Norway maple	*A. platanoides*	Mn
*Sycamore maple	*A. pseudoplatanus*	Ms
Oak	***Quercus***	**Q**
*English oak	*Q. robur*	Qe
*white oak	*Q. alba*	Qw
Other exotics		
*incense-cedar	Calocedrus decurrens	Oa
*giant sequoia	*Sequoiadendron giganteum*	Ob
*coast redwood	*Sequoia sempervirens*	Oc
European mountain-ash	*Sorbus aucuparia*	Od
Siberian elm	*Ulmus pumila*	Oe
common pear	*Pyrus communis*	Of

Common name	Scientific Name	Code
Oregon ash	*Fraxinus latifolia*	Og
*white ash	*Fraxinus Americana*	Oh
*shagbark hickory	*Carya ovata*	Oi
Pine	***Pinus***	**P**
*Monterey pine	*P. radiate*	Pm
*red pine	*P. resinosa*	Pr
*sugar pine	*P. lambertiana*	Ps
Spruce	***Picea***	**S**
*Norway spruce	*P. abies*	Sn

Changes to Version 4 of B.C. Ministry of Forests Tree Code List

1. Exotic species added to list: a) to provide codes for database purposes (requested by Resources Inventory Branch); and b) to accommodate inventories being conducted near areas of settlement that may encounter escaped or naturalized exotics.
2. Hybrids that cannot be easily distinguished or are of doubtful existence were deleted from list. Operational option is to go to upper level generic code if suspected hybrids without codes are encountered; common hybrids still have codes. Deletions include: Sxe (*Picea engelmannii* x *sitchensis*), Sxb (*Picea glauca* x *mariana*), Sxx (*Picea glauca* x *engelmannii* x *sitchensis*), and Exw (*Betula occidentalis* x *papyrifera*).
3. Dm (*Alnus tenuifolia*) deleted as it is not known to exceed 10 m in height and is most often multi-stemmed.

Changes to Version 4.1 of B.C. Ministry of Forests Tree Code List

Sn (*Picea abies*) Norway Spruce was added. Note that some printed copies of version 4.0 had Norway spruce included but our master version required the update hence the minor version upgrade.

Changes to Version 4.2 of B.C. Ministry of Forests Tree Code List

Four exotic species requiring codes for database purposes were added: yellow birch (Ey), white ash (Oh), shagbark hickory (Oi), and white oak (Qw).

Changes to Version 4.3 of B.C. Ministry of Forests Tree Code List

One exotic species requiring a code for database purposes was added: Dahurian larch (Ld).

Appendix E: Completing the Field Forms

Sample Field Card A: Polygon Sampling Header Card (PH)

Sample Field Card B: Polygon Compass Card (PC)

Sample Field Card C: Polygon Sampling Card (full measure plot details) (PS)

Sample Field Card C: Polygon Sampling Card (count plot details) (PS)

Sample Field Card D: Polygon Site Tree Data Card (PT)

BRITISH COLUMBIA

VEGETATION RESOURCES INVENTORY
POLYGON SAMPLING HEADER CARD (PH)

A

Measurement Date: YEAR MON DD

Crew (Initials): Person #1 | Person #2 | Person #3 | Person #4

Start: 2000 JUL 21 — Person #1: DRH — Person #2: JAH — Person #3: AGO — Person #4: WGS

Finish: 2000 JUL 23

Project ID: 00291

Polygon No: 37

Plot Type: W01

Block / Other:

Map No: 92P082

Polygon No: 1068

Flight Line: 30BCC95078

Photo No: 063

Integrated Plot Centre: 92P082 37

Tie Point:

Field Responsibility (print)

Field Check By

Date: YEAR MON DD

Office Check By

Date: YEAR MON DD

A

Crew #1: P. HATCH

Crew #2: J. HATCH

Plot Cluster Record

Comments: Sunny and hot

Plots Completed: 35

Plots Planned: 35

Comments (for plots not completed)

Tie Point Description: The point is centerline of "Y" junction on southedge of polygon

Corrector Weather, photo notes, procedure problems

FS 5058 (08-01)

Figure A1: Sample Field Card A: Polygon Sampling Header Card (PH)

Figure A2: Sample Field Card B: Polygon Compass Card (PC)

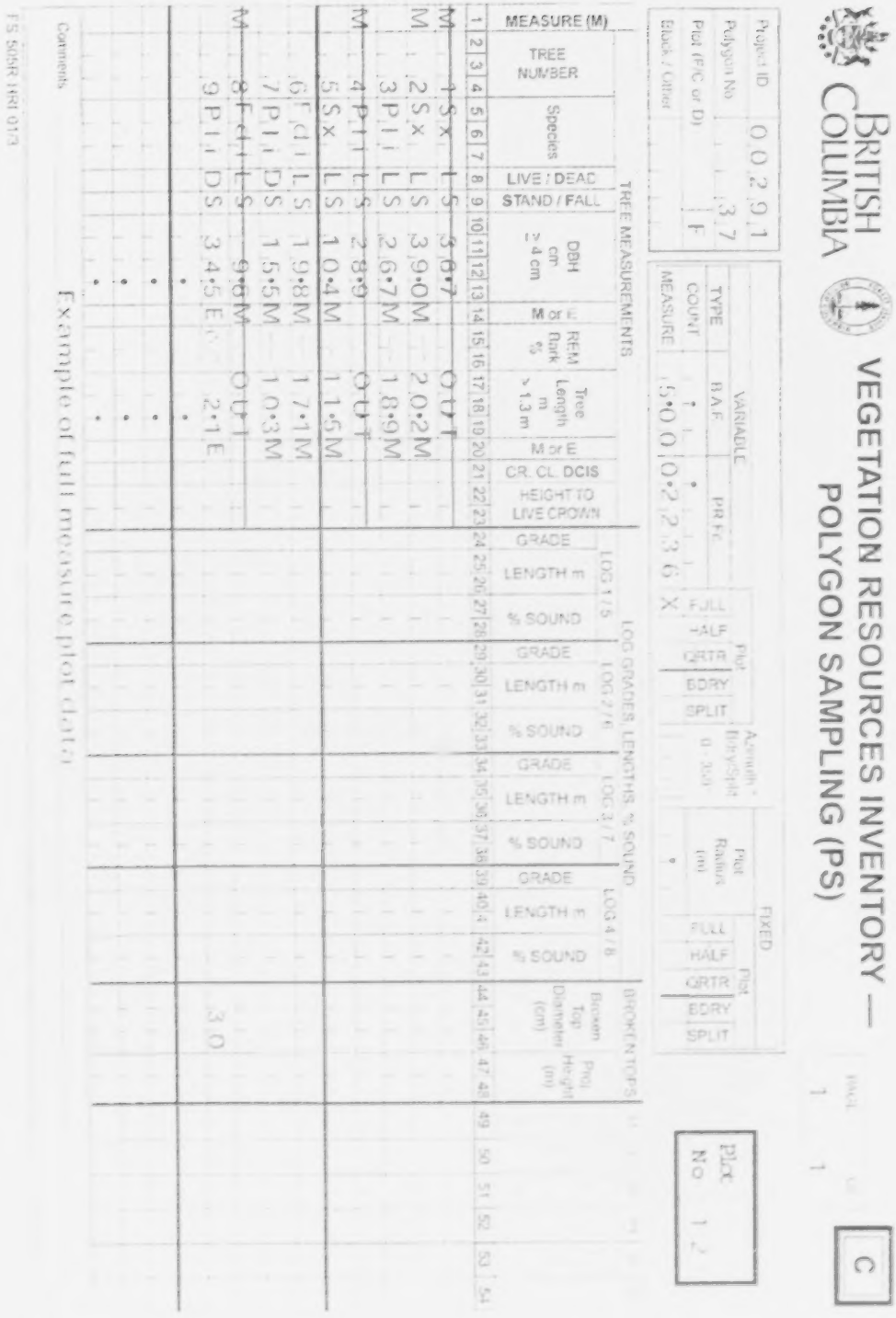


Figure A3: Sample Field Card C: Polygon Sampling Card (full measure plot details) (PS)

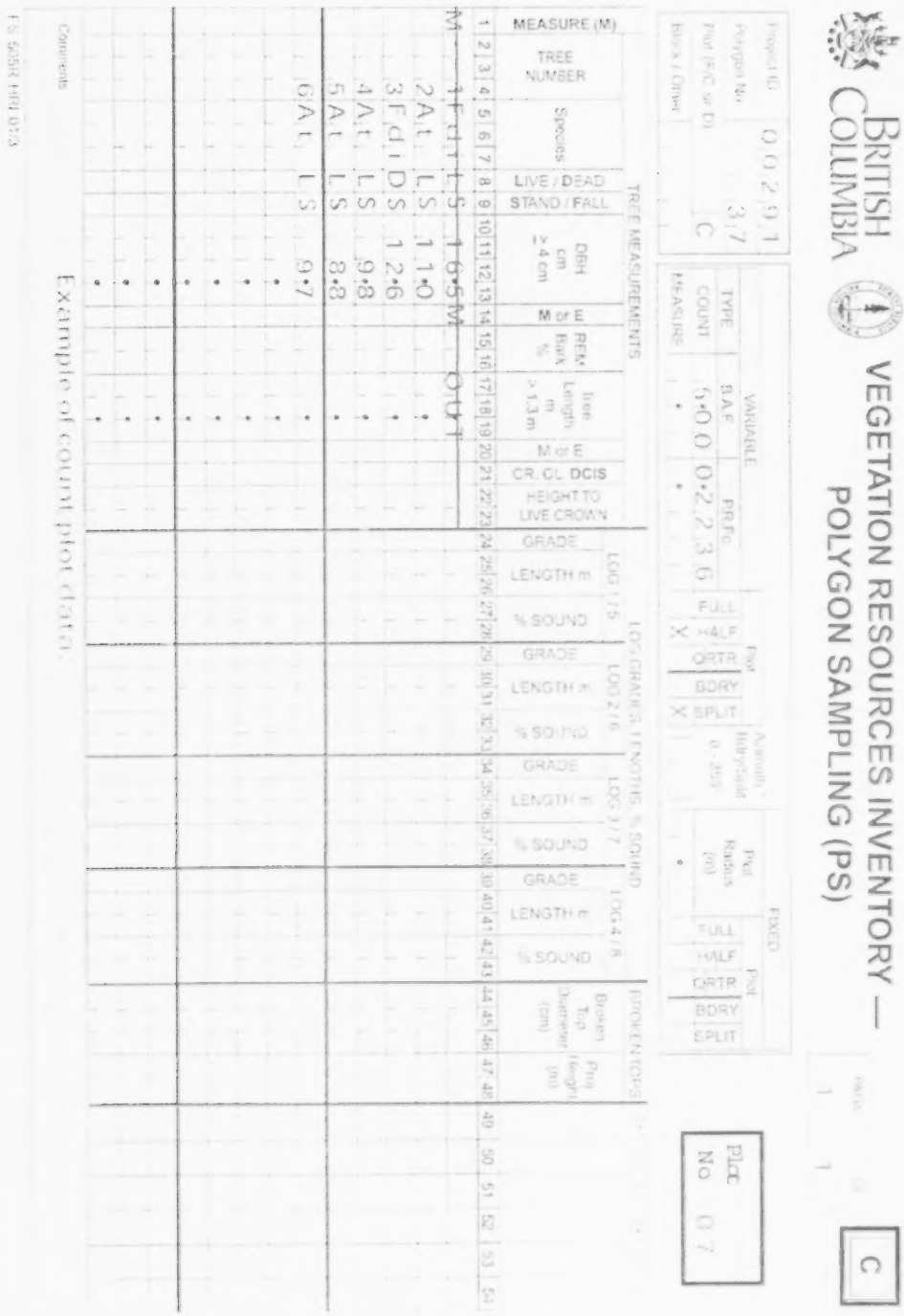


Figure A4: Sample Field Card C: Polygon Sampling Card (count plot details) (PS)

BRITISH COLUMBIA

VEGETATION RESOURCES INVENTORY
POLYGON SITE TREE DATA (PT)

PAGE 1 OF 1

D

Project ID 0 0 2 9 1 Polygon/Stock No 3 7

Plot No 1 2

TOP HEIGHT AND SITETREE INFORMATION

* T = Top height tree

Plot Type	Tree No	W/E TYPE	Species	Cr/Cl	Boring (OB) Diam. (cm)	Tree Length (m)	S/I Thickness (mm)	Bark Thickness (mm)	Btwnd Height (m)	Measure Code	Offset Breast Height Age	Growth (mm) 5 Yr	10 Yr	20 Yr	Prorate Data Length (cm)	Dif Count	Direct Age Corr	Total Age	Phy Age
1	2 3	4	5	6	7	8	9 10	11 12	13 14	15 16	17	18 19	20 21	22 23	24 25	26 27	28 29	30 31	32 33	34 35	36 37	38 39	40 41	42 43	44 45	46 47	48 49	50 51	52
5.64 m		T																											
5.64 m		L					none available																						
	3	S	P	I	C		26.7		18.9	Y			1.3	-	-														Y

FIELD AGE COUNT

Tree No	TYPE	HEIGHT AGE
	T	
3	S	173

Comments: Spruce #5 is intermediate crown class, therefore not suitable for site tree. Tree #2 is out of 5.64 m plot.

GPS Plot Centre

File ID

UTM Zone

Corrected UTM (NAD 83)

Northing

Easting

Elevation

WORKSHEET

DATA WILL NOT BE KEYPUNCHED

* Center or Face

TREE NO	DBH (cm)	1/2 DBH (cm)	SLOPE DISTANCE (m)	CF*	% SLOPE	HORIZ. DIST. (m)	CRITICAL DIST OR DIAMETER	C/F	I/D	+/-	TOP %	+/-	BTM %	TOTAL %	COR	LENGTH (m)
1	36.7		8.38	4	8.37	8.21	C	Ø								
2	39.0		7.45	-	7.45	8.72	C	1								
4	28.9		8.08	-	8.08	6.46	C	O								
8	9.6		2.34	-	2.34	2.15	C	O								

Figure A5: Sample Field Card D: Polygon Site Tree Data Card (PT)

Appendix F: Example of Polygon Sampling Field Map